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# ATS-5 DESPIN-MISSION MAGNETIC INVESTIGATION


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GSFC

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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SUMMARY

During March and April 1970, the Goddard Space Flight Center (GSFC) Magnetic Test Site tested apparatus for determining the feasibility of the proposed magnetic-despin concept for correcting attitude problems of spacecraft already in orbit. The GSFC Mark VI torquemeter was used to measure magnetic torques at various fixer-satellite and malfunctioning-satellite separation distances and angular orientations. The varying magnetic field, that a probe on board the despin satellite would view, caused by spin of the malfunctioning satellite was also measured.

The data obtained will be used to refine the mathematical model of the actual despin system.

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# ATS-5 DESPIN-MISSION MAGNETIC INVESTIGATION

## INTRODUCTION

In response to a request by W. C. Isley and Dr. Franz Zach of the Auxiliary Propulsion Branch, GSFC, a despin-satellite concept has been proposed for correcting attitude problems of spacecraft already in orbit (e.g., ATS-5) so that they can successfully accomplish their intended mission. Although ATS-5 was designed to be gravity-gradient stabilized, it is now spinning at 76 rpm. Because of difficulties encountered at final injection into orbit, the spacecraft cannot despin itself.

One method proposed for despinning ATS-5 is to use a despin satellite which will keep station with the spacecraft in its near vicinity. The despin satellite will contain a number of powerful electromagnets and will be attitude-controlled to keep the magnets pointing at ATS-5. Because ATS-5 also contains electromagnets, an interaction torque will be generated. By reversing the magnetic moment of the despin-satellite electromagnets at the proper time, the direction of the torque generated will serve to despin ATS-5 and to eventually bring it to a standstill.

## PURPOSE OF TESTS

The purpose of the tests was to obtain experimental results for comparison with those obtained from a mathematical model. In this way, the mathematical model can be refined so that a high degree of confidence can be assigned to predictions for actual despin performance.

Two electromagnets were obtained to aid in the evaluation of the magnetic-torquer concept. These electromagnets are not necessarily identical to those which will be used in an actual mission. Use of these electromagnets and the GSFC Mark VI torquemeter has made it possible to simulate the space environment and to measure the retarding torques which are generated.

## TEST DESCRIPTION

All torque testing was done in either the Magnetic Instrument Test Laboratory or the Spacecraft Magnetic Test Facility at the GSFC Magnetic Test Site. These facilities can produce a highly stable magnetic environment at either zero field or any other desired level up to 60,000 gammas.

Figure 1 shows the setup used to determine the magnetic moments of the electromagnets. The electromagnet was mounted on the Mark VI torquemeter at the approximate center of the coil system. The torque which results when the coil system applies a known field vector is proportional to the magnetic moment of the magnet under test.

Fields of 60,000 gammas were applied in the north and south directions and the resulting torque was measured. One set of measurements was made with the electromagnets in their "as-received" condition; another set was made after the electromagnets had been charged by the capacitor bank. Table 1 summarizes the results of these tests.

In Figure 2, one electromagnet (simulating the despin torquer) was mounted on a rotatable nonmagnetic stand so that its position could be reversed. The other electromagnet was mounted at the approximate center of the coil system on the Mark VI torquemeter. This magnet was displaced from the center of twist of the torquemeter and was mounted on a rotatable plywood support so that it could be placed in a series of angular orientations (simulating the torquer rods in the ATS-5 spacecraft).

For these tests, the ATS simulator magnet was mounted on the torquemeter and set in a series of angular orientations from 0 to 360 degrees at 10-degree increments. The torquemeter was read with the ATS magnet in a given position. The despin magnet was then turned end-for-end and the torquemeter was again read. Half the difference between these readings was taken as the value of the interaction torque. The coil systems were programmed to produce zero field.

The tests were performed with the magnets in both "as-received" and charged conditions. In addition, torque data were obtained at several separation distances and at two angular positions of the despin magnet. Tables 2, 3, 4, and 5 list the data obtained during these tests.

Figure 3 shows the arrangement used in charging the electromagnets, including the charging circuitry. The dc power supply charged the capacitor bank to the desired voltage level, and the energy was discharged into the winding of the electromagnet in a single pulse. The diode across the capacitor output prevented ring-down oscillations. The Hall probe was maintained at a fixed distance from the end of the electromagnet to indicate relative changes in strength of the electromagnet as it was charged or discharged.

Using the equipment shown in Figure 3, the capacitor bank was charged to a selected voltage after which it was discharged into the magnet coil. The field sensed by the Hall probe was measured after each discharge. A compass was used to verify the direction of the magnetic moment of the electromagnet. Various

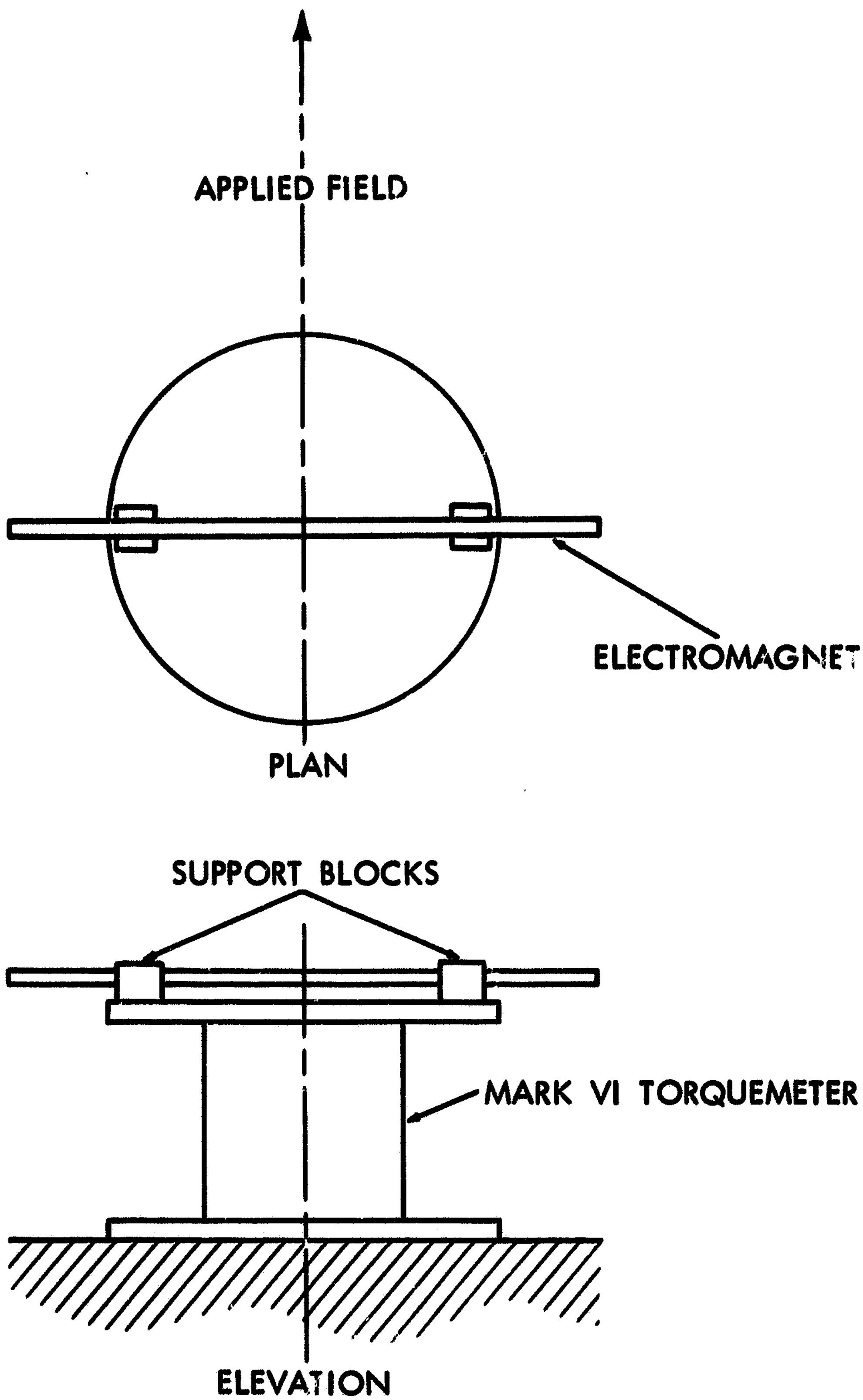


Figure 1. Test Setup for Magnetic-Moment Measurement

Table 1
ATS-5 Despin-Mission Magnetic-Moment Determination*

| Magnet | State | Sensitivity (mv/mm) | Divisions | Calibration Factor (dyne-cm/div) | Torque (dyne-cm) | Direction | Applied Field | Magnetic Moment (pole-cm) |
|---|---|---|---|---|---|---|---|---|
| 103 | As received | 50 | 26.5 | 223.5 | 5,920 | CW | 60 KγN | 9,870 |
| 104 | As received | 50 | 28.0 | 223.5 | 6,260 | CCW | 60 KγN | 10,430 |
| 103 | Fully charged | 100 | 24.0 | 1180.0 | 28,320 | CW | 60 KγN | 47,200 |
| 104 | Fully charged | 100 | 24.0 | 1180.0 | 28,320 | CW | 60 KγN | 47,200 |

*Using setup shown in Figure 1

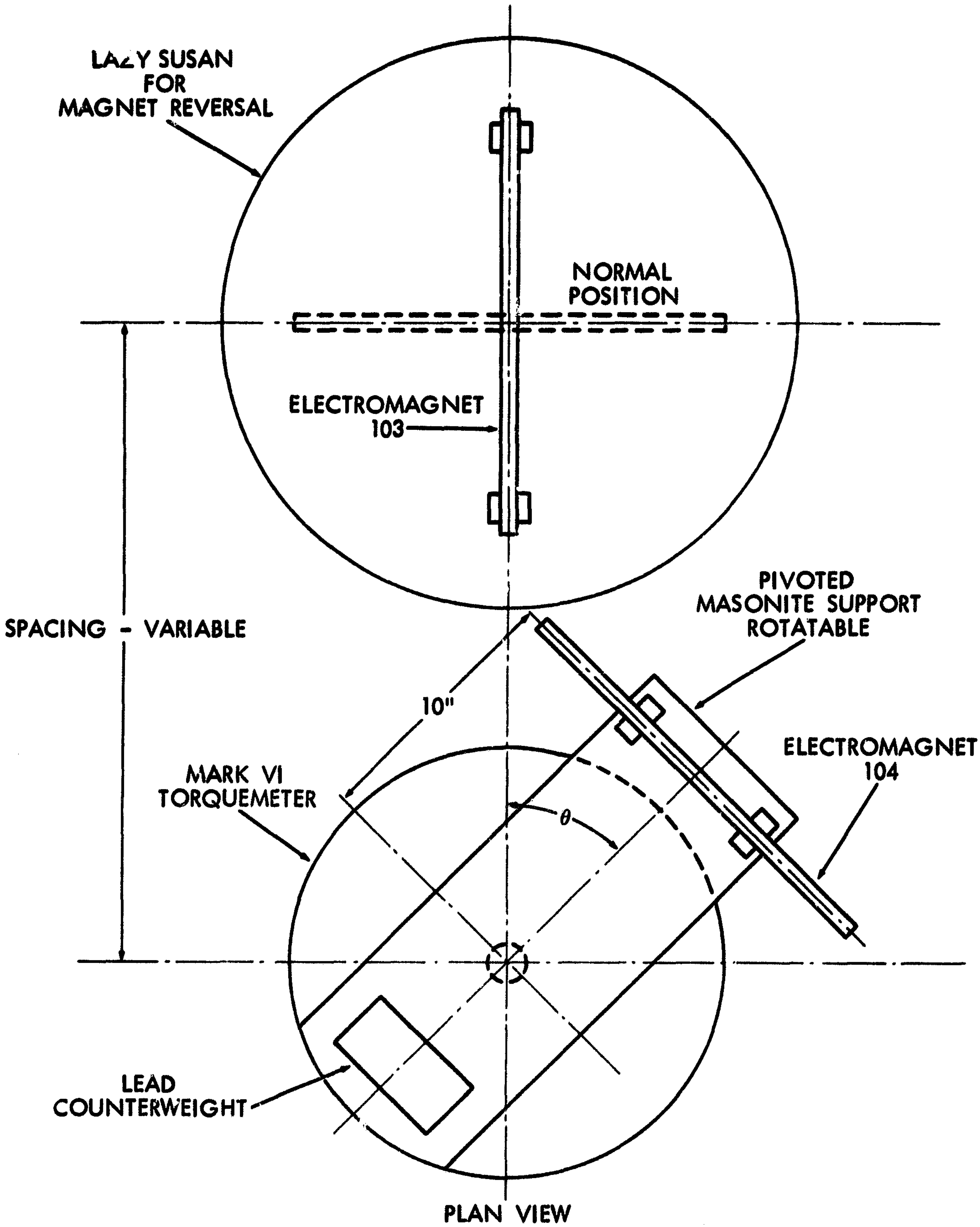



**Figure 2. Test Setup for Despin-Torque Measurement**

## Table 2
## ATS-5 Despin-Torque Test, March 26, 1970*
## (as received)

| θ (degrees) | Divisions | Sensitivity | Torque (dyne-cm) | Direction | Calibration Factor |
|---|---|---|---|---|---|
| Cal | 24.5 | 20 mv/mm | 1960 | CCW | 80 dyne-cm/div |
| 0 | 25.5 | 50 mv/mm | 2560 | CCW | |
| 10 | 27.0 | 50 mv/mm | 2700 | CCW | |
| Cal | 20.0 | 20 mv/mm | 1960 | CCW | 98 dyne-cm/div |
| 20 | 20.0 | 50 mv/mm | 2450 | CCW | |
| 30 | 16.0 | 50 mv/mm | 1960 | CCW | |
| 40 | 9.5 | 20 mv/mm | 466 | CCW | |
| 50 | 28.0 | 20 mv/mm | 1370 | CW | |
| 60 | 38.5 | 20 mv/mm | 1890 | CW | |
| 70 | 32.0 | 20 mv/mm | 1570 | CW | |
| 80 | 23.0 | 20 mv/mm | 1130 | CW | |
| 90 | 16.5 | 20 mv/mm | 810 | CW | |
| 100 | 10.5 | 20 mv/mm | 515 | CW | |
| 110 | 16.0 | 10 mv/mm | 390 | CW | |
| 120 | 12.5 | 10 mv/mm | 310 | CW | |
| 130 | 10.0 | 10 mv/mm | 245 | CW | |
| 140 | 16.0 | 5 mv/mm | 196 | CW | |
| 150 | 15.0 | 5 mv/mm | 183 | CW | |
| 160 | 11.0 | 5 mv/mm | 135 | CW | |
| 170 | 9.0 | 5 mv/mm | 110 | CW | |
| 180 | 10.0 | 5 mv/mm | 123 | CW | |
| 190 | 10.5 | 5 mv/mm | 129 | CW | |
| 200 | 12.0 | 5 mv/mm | 147 | CW | |
| 210 | 13.0 | 5 mv/mm | 160 | CW | |
| 220 | 16.5 | 5 mv/mm | 202 | CW | |
| 230 | 20.0 | 5 mv/mm | 245 | CW | |
| 240 | 12.5 | 10 mv/mm | 306 | CW | |
| 250 | 15.5 | 10 mv/mm | 380 | CW | |
| 260 | 22.5 | 10 mv/mm | 550 | CW | |
| 270 | 16.0 | 20 mv/mm | 784 | CW | |
| 280 | 22.0 | 20 mv/mm | 1080 | CW | |
| 290 | 30.0 | 20 mv/mm | 1470 | CW | |
| 300 | 14.0 | 0.5 v/cm | 1720 | CW | |
| 310 | 23.5 | 20 mv/mm | 1150 | CW | |
| 320 | 8.0 | 20 mv/mm | 392 | CCW | |
| 330 | 33.5 | 20 mv/mm | 1640 | CCW | |
| 340 | 18.0 | 0.5 v/cm | 2220 | CCW | |
| 350 | 20.0 | 0.5 v/cm | 2450 | CCW | |
| 360 | 20.0 | 0.5 v/cm | 2450 | CCW | |
| 10 | 20.5 | 0.5 v/cm | 2510 | CCW | |
| 300 | 33.5 | 20 mv/mm | 1640 | CW | |

*Using setup shown in Figure 2

## Table 3
## ATS-5 Despin-Torque Test with Torquer Normal*
## (as received)

| θ (degrees) | Sensitivity (mv/mm) | Divisions | Scale Factor | Torque (dyne-cm) | Sense | Calibration Factor |
|---|---|---|---|---|---|---|
| Cal | 20 | 19.5 | – | 1960 | CCW | 101 dyne-cm/div |
| 0 | 10 | 0.5 | 0.5 | 25 | CCW | |
| 10 | 10 | 13.0 | 0.5 | 657 | CW | |
| 20 | 10 | 27.0 | 0.5 | 1364 | CW | |
| 30 | 20 | 18.0 | 1.0 | 1818 | CW | |
| 40 | 20 | 20.0 | 1.0 | 2020 | CW | |
| 50 | 20 | 18.0 | 1.0 | 1818 | CW | |
| 60 | 10 | 21.5 | 0.5 | 1060 | CW | |
| 70 | 10 | 10.0 | 0.5 | 505 | CW | |
| 80 | 10 | 0.5 | 0.5 | 25 | CCW | |
| 90 | 10 | 3.0 | 0.5 | 152 | CCW | |
| 100 | 5 | 10.5 | 0.25 | 265 | CCW | |
| 110 | 5 | 11.0 | 0.25 | 278 | CCW | |
| 120 | 5 | 8.0 | 0.25 | 109 | CCW | |
| 130 | 5 | 8.0 | 0.25 | 109 | CCW | |
| 140 | 2 | 11.0 | 0.1 | 111 | CCW | |
| 150 | 2 | 9.0 | 0.1 | 91 | CCW | |
| 160 | 2 | 6.0 | 0.1 | 61 | CCW | |
| 170 | 2 | 5.0 | 0.1 | 50 | CCW | |
| 180 | 2 | 1.5 | 0.1 | 15 | CW | |
| 190 | 2 | 1.0 | 0.1 | 10 | CW | |
| 200 | 2 | 7.0 | 0.1 | 71 | CW | |
| Cal | 20 | 19.0 | – | 1960 | CCW | 103 dyne-cm/div |
| 210 | 2 | 9.0 | 0.1 | 92 | CCW | |
| 220 | 2 | 11.0 | 0.1 | 112 | CCW | |
| 230 | 2 | 14.0 | 0.1 | 143 | CCW | |
| 240 | 2 | 21.0 | 0.1 | 214 | CCW | |
| 250 | 5 | 9.0 | 0.25 | 229 | CCW | |
| 260 | 2 | 17.0 | 0.1 | 173 | CCW | |
| 270 | 2 | 4.5 | 0.1 | 46 | CCW | |
| 280 | 2 | 13.0 | 0.1 | 133 | CW | |
| 290 | 5 | 22.0 | 0.25 | 561 | CW | |
| 300 | 5 | 44.0 | 0.25 | 1122 | CW | |
| 310 | 10 | 32.5 | 0.5 | 1658 | CW | |
| 320 | 10 | 37.0 | 0.5 | 1887 | CW | |
| 330 | 10 | 32.5 | 0.5 | 1658 | CW | |
| 340 | 10 | 24.0 | 0.5 | 1224 | CW | |
| 350 | 10 | 11.0 | 0.5 | 561 | CW | |
| 360 | 2 | 4.5 | 0.1 | 46 | CCW | |
| Cal | 20 | 19.0 | 1.0 | 1960 | CCW | 103 dyne-cm/div |

*Using setup shown in Figure 2

## Table 4
## ATS-5 Despin-Torque Test*
## (fully charged)

| θ | P-P Defl. | Sanborn Sensitivity | Torque | |
|---|---|---|---|---|
| | | | Magnitude (dyne-cm) | Direction |
| 1. Separation - 2' -8-1/4" R = 10" Calibration = 60.3 dyne-cm/div at 5 mv/mm on 5 scale | | | | |
| 0 | 32.5 | 2 v/cm | 39,200 | CW |
| 10 | 32.0 | 2 v/cm | 38,700 | CW |
| 20 | 29.5 | 2 v/cm | 35,500 | CW |
| 30 | 30.0 | 2 v/cm | 24,100 | CW |
| 40 | 3.5 | 2 v/cm | 4,220 | CW |
| 50 | 26.5 | 1 v/cm | 15,950 | CCW |
| 60 | 38.0 | 1 v/cm | 22,900 | CCW |
| 70 | 17.0 | 2 v/cm | 20,500 | CCW |
| 80 | 13.5 | 2 v/cm | 16,250 | CCW |
| 90 | 21.0 | 1 v/cm | 12,650 | CCW |
| 100 | 15.5 | 1 v/cm | 9,330 | CCW |
| 120 | 8.5 | 1 v/cm | 5,110 | CCW |
| 140 | 10.5 | 0.5 v/cm | 3,160 | CCW |
| 160 | 3.5 | 20 mv/mm | 420 | CCW |
| 180 | 19.0 | 20 mv/mm | 2,290 | CCW |
| 2. Separation - 7' -6-7/8" Calibration = $\frac{1967}{17}$ = 115.6 dyne-cm/div at 1 v/cm on 3 scale | | | | |
| 30 | 14.0 | 1.0 v/cm | | CW |
| 40 | 10.5 | 0.5 v/cm | | CW |
| 50 | 5.5 | 0.5 v/cm | | CW |
| 60 | 3.0 | 0.5 v/cm | | CW |
| 70 | 0.0 | 0.5 v/cm | | – |
| 80 | 4.0 | 0.5 v/cm | | CCW |
| 3. Separation - 4' -1-1/2" Calibration = $\frac{1967}{35}$ = 56.2 dyne-cm/div at 0.[illegible] cm on 3 scale | | | | |
| 30 | 28.0 | 2 v/cm | | CW |
| 40 | 14.0 | 2 v/cm | | CW |
| 50 | 1.0 | 2 v/cm | | CW |
| 60 | 9.5 | 2 v/cm | | CCW |
| 4. Separation = 5' -3-3/4" Calibration: None | | | | |
| 40 | 24.0 | 0.5 v/cm | | CW |
| 50 | 10.0 | 0.5 v/cm | | CW |
| 60 | 5.0 | 0.5 v/cm | | CCW |

*Using setup shown in Figure 2

**Table 5**
**ATS-5 Despin Electromagnet Moments***
**(charged state)**

| Calibration = 5900 ÷ 24.5 = 241 dyne-cm/div at 20 mv/mm on 5 scale | | | | | | |
|---|---|---|---|---|---|---|
| Magnet | Div Defl. | Sensitivity (v/cm) | Torque | | Field | Magnetic Moment (pole-cm) |
| | | | Magnitude (dyne-cm) | Direction | | |
| 104 | 24 | 1 | 28,900 | CW | 60 K$\gamma$ N | 48,200 |
| 104 | 24 | 1 | 28,900 | CCW | 60 K$\gamma$ S | 48,200 |
| 103 | 24 | 1 | 28,900 | CW | 60 K$\gamma$ N | 48,200 |
| 103 | 24 | 1 | 28,900 | CCW | 60 K$\gamma$ S | 48,200 |

*Using setup shown in Figure 1

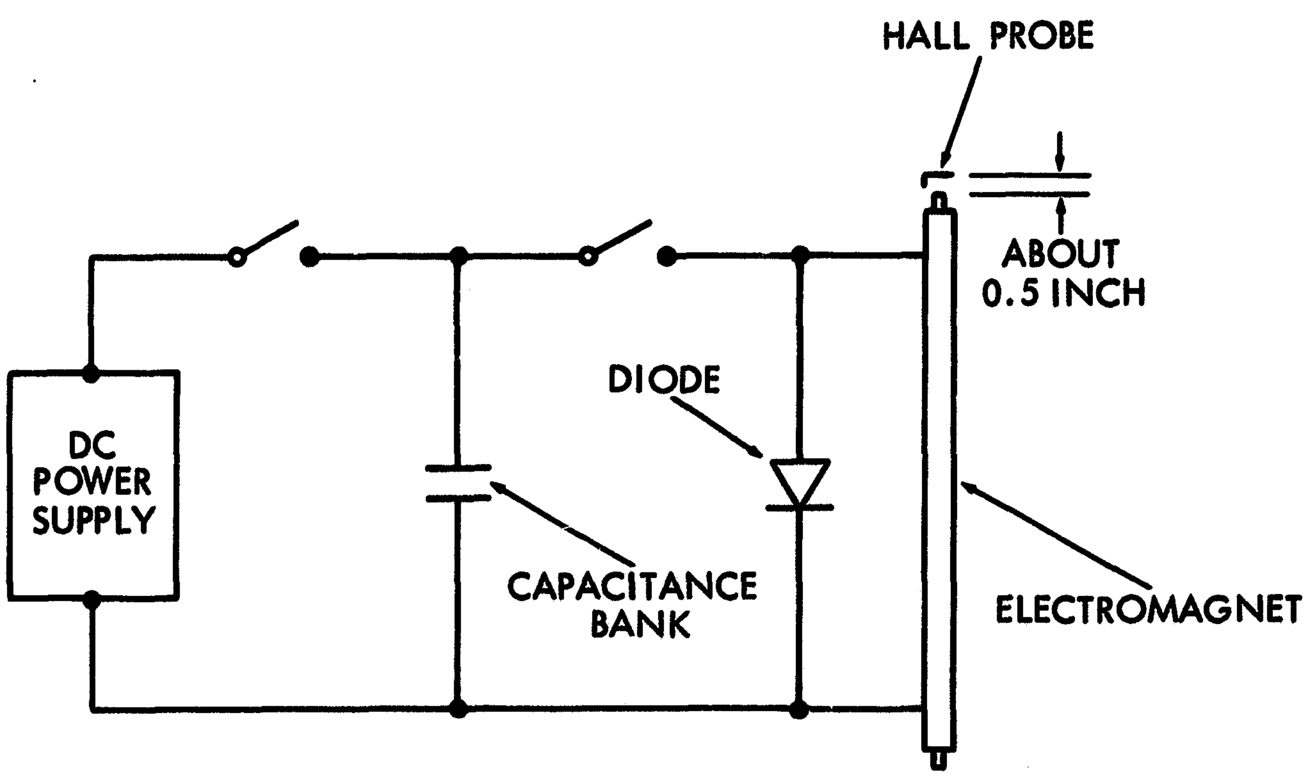



Figure 3. Electromagnet Charging Circuitry

total capacitance and voltage levels were used in these tests. In addition, the time required for charging and discharging the capacitors was approximated by observing a cathode-ray-tube display. Table 6 lists the data obtained.

A series of tests was performed to investigate the feasibility of using a magnetometer on board the despin satellite to monitor the magnetic field produced by the ATS satellite as it rotates. It was believed that the measurement of the ATS field as it rotated might serve as an indication of its angular orientation with respect to the despin satellite. If so, the field measurement would indicate the proper instant to reverse the magnetic moment of the despin magnets so that the torque applied would not reverse, but would always be in the proper direction to retard the ATS.

Figure 4 shows the setup used to perform these tests. The first step was to remove magnet 104 from the facility and then to change the angular position of magnet 103 slowly until only a small field (approximately 5 to 10 gammas) was read by the Z probe of the magnetometer. Magnet 104 was then placed in the position shown in Figure 4 and rotated by the adjustable-speed motor at a period of about 5 seconds per revolution. Simultaneously, the Z component of field was recorded on the Sanborn recorder. Data were obtained at two different separation distances and with several settings of the electric filter. Figures 5 through 7 show typical records obtained.

## TEST RESULTS AND DISCUSSIONS

### Magnetic-Moment Measurement

The magnetic moments of the electromagnets in their "as-received" condition were:

Magnet 103 = 9,850 pole-cm

Magnet 104 = 10,450 pole-cm

After charging to maximum residual magnetism (remanent perm), the magnetic moments were:

Magnet 103 = 47,200 pole-cm

Magnet 104 = 47,200 pole-cm

## Table 6
## ATS-5 Despin Magnetic-Charging Test*

| Capacity (μf) | Voltage | Charge Number | Flux Density (gauss) | Capacity (μf) | Voltage | Charge Number | Flux Density (gauss) | Capacity (μf) | Voltage | Charge Number | Flux Density (gauss) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 100 | 0 | | 7.00 | 100 | +40 | 20 | 17.35 | 150 | +112 | 1 | +30.0 |
| 100 | +20 | 1 | 7.15 | 100 | +50 | 1 | 19.8 | 150 | +112 | 2 | +35.0 |
| 100 | +20 | 2 | 7.27 | 100 | +50 | 2 | 22.7 | 350 | +112 | 1 | +36.1 |
| 100 | +20 | 3 | 7.38 | 100 | +50 | 3 | 24.3 | 350 | +112 | 2 | +36.1 |
| 100 | +20 | 4 | 7.39 | 100 | +50 | 4 | 25.3 | 350 | -112 | 1 | -36.6 |
| 100 | +20 | 5 | 7.39 | 100 | +50 | 5 | 25.3 | 350 | -112 | 2 | -36.9 |
| 100 | +30 | 1 | 7.79 | 100 | +50 | 6 | 26.0 | 350 | +112 | 1 | +35.7 |
| 100 | +30 | 2 | 7.86 | 100 | +55 | 1 | 27.5 | 350 | +112 | 2 | +35.7 |
| 100 | +30 | 3 | 7.90 | 100 | +55 | 2 | 28.0 | 350 | -112 | 1 | -36.1 |
| 100 | +30 | 4 | 7.91 | 100 | +55 | 3 | 28.0 | 350 | -112 | 2 | -36.6 |
| 100 | +30 | 5 | 7.99 | 100 | +55 | 4 | 28.2 | 350 | -100 | 1 | -36.7 |
| 100 | +30 | 6 | 8.10 | 100 | +70 | 1 | 30.8 | 350 | +100 | 1 | +35.0 |
| 100 | +30 | 7 | 8.65 | 100 | +70 | 2 | 31.4 | 350 | +100 | 2 | +35.8 |
| 100 | +30 | 8 | 8.62 | 100 | +70 | 3 | 31.6 | 350 | +100 | 3 | +35.8 |
| 100 | +30 | 9 | 8.65 | 100 | +80 | 1 | 32.7 | 350 | -100 | 1 | -35.7 |
| 100 | +40 | 1 | 9.48 | 100 | +80 | 2 | 33.0 | 350 | -100 | 2 | -36.6 |
| 100 | +40 | 2 | 10.0 | 100 | +80 | 3 | 33.1 | 350 | -100 | 3 | -36.6 |
| 100 | +40 | 3 | 10.65 | 100 | +100 | 1 | 34.4 | 350 | +100 | 1 | +35.0 |
| 100 | +40 | 4 | 11.1 | 100 | +100 | 2 | 34.6 | 350 | +80 | 1 | +35.1 |
| 100 | +40 | 5 | 11.5 | 100 | +100 | 3 | 34.7 | 350 | -80 | 1 | -32.5 |
| 100 | +40 | 6 | 11.8 | 100 | +100 | 4 | 34.7 | 350 | -80 | 2 | -35.6 |
| 100 | +40 | 7 | 12.4 | | | | | 350 | -80 | 3 | -35.7 |
| 100 | +40 | 8 | 13.0 | 150 | +100 | 1 | 35.1 | 350 | +80 | 1 | +31.8 |
| 100 | +40 | 9 | 13.6 | 150 | +100 | 2 | 35.2 | 350 | +80 | 2 | +34.5 |
| 100 | +40 | 10 | 14.2 | 150 | +112 | 1 | 35.6 | 350 | +80 | 3 | +34.5 |
| 100 | +40 | 11 | 14.6 | 150 | +112 | 2 | 35.7 | 350 | +60 | 1 | +34.3 |
| 100 | +40 | 12 | 14.85 | 150 | -112 | 1 | -33.0 | 350 | -60 | 1 | -13.5 |
| 100 | +40 | 13 | 15.45 | 150 | -112 | 2 | -36.5 | 350 | -60 | 2 | -29.6 |
| 100 | +40 | 14 | 16.1 | 150 | +112 | 1 | +32.2 | 350 | -60 | 3 | -32.8 |
| 100 | +40 | 15 | 16.3 | 150 | +112 | 2 | +35.5 | 350 | -60 | 4 | -33.5 |
| 100 | +40 | 16 | 16.7 | 150 | -112 | 1 | -36.2 | 350 | +60 | 1 | +13.3 |
| 100 | +40 | 17 | 16.75 | 150 | -112 | 2 | -36.5 | 350 | +60 | 2 | +30.8 |
| 100 | +40 | 18 | 17.25 | | | | | 350 | +60 | 3 | +31.6 |
| 100 | +40 | 19 | 17.25 | | | | | 350 | +60 | 4 | +32.5 |

*Setup as shown in Figure 3

Time required to reverse charge = 0.020 seconds

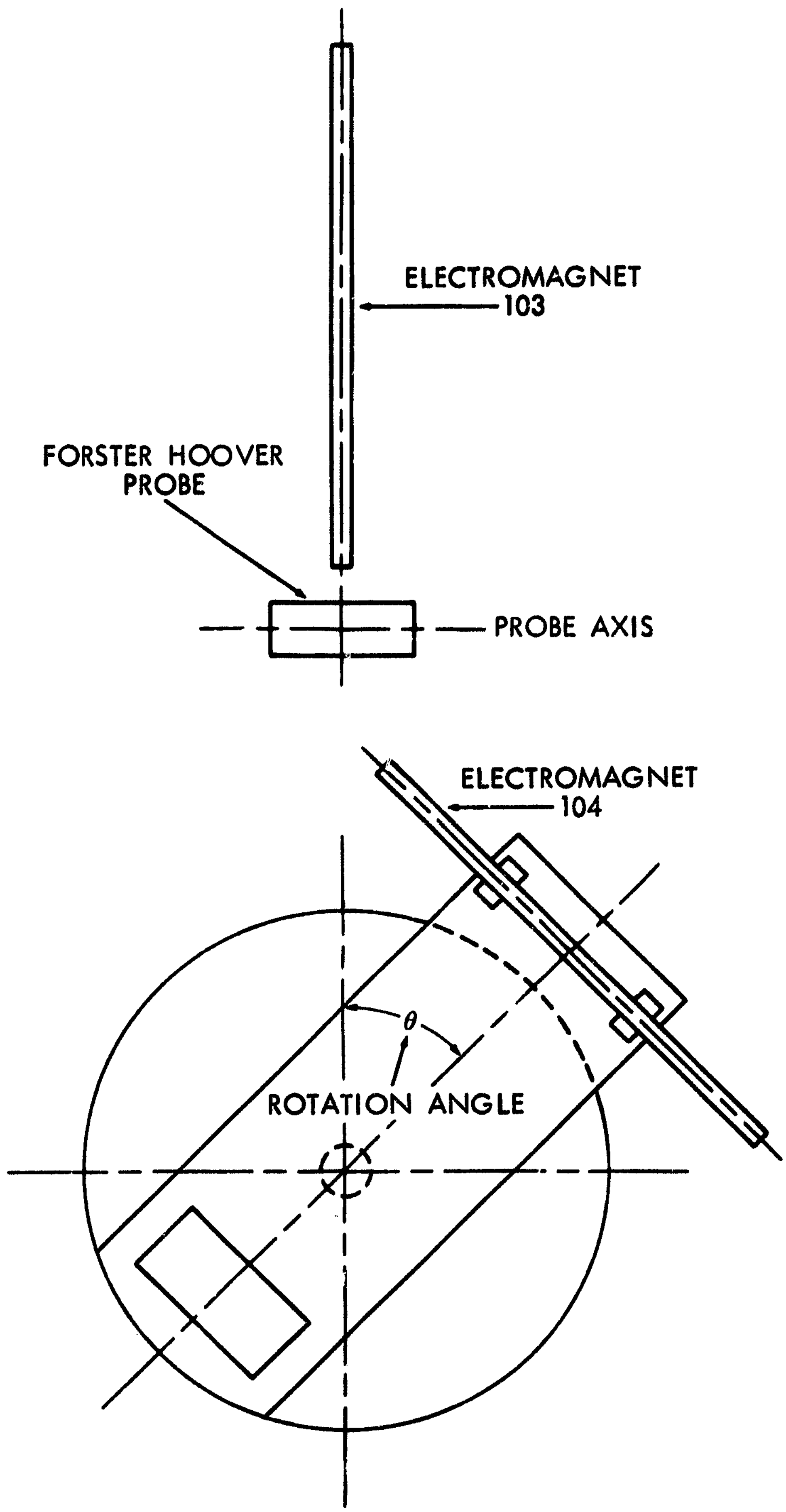



Figure 4. Test Setup for Magnet Signature Measurement

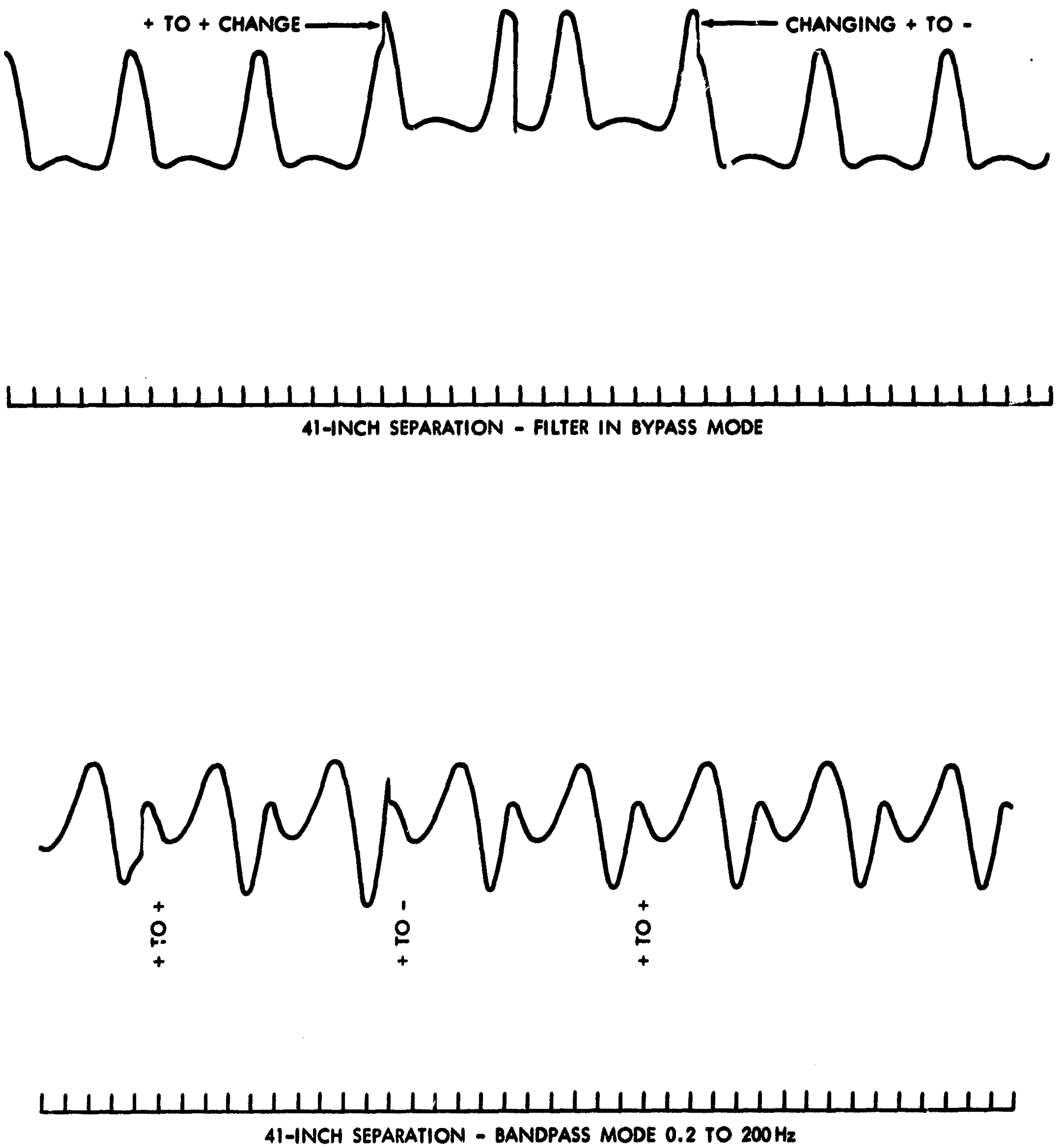
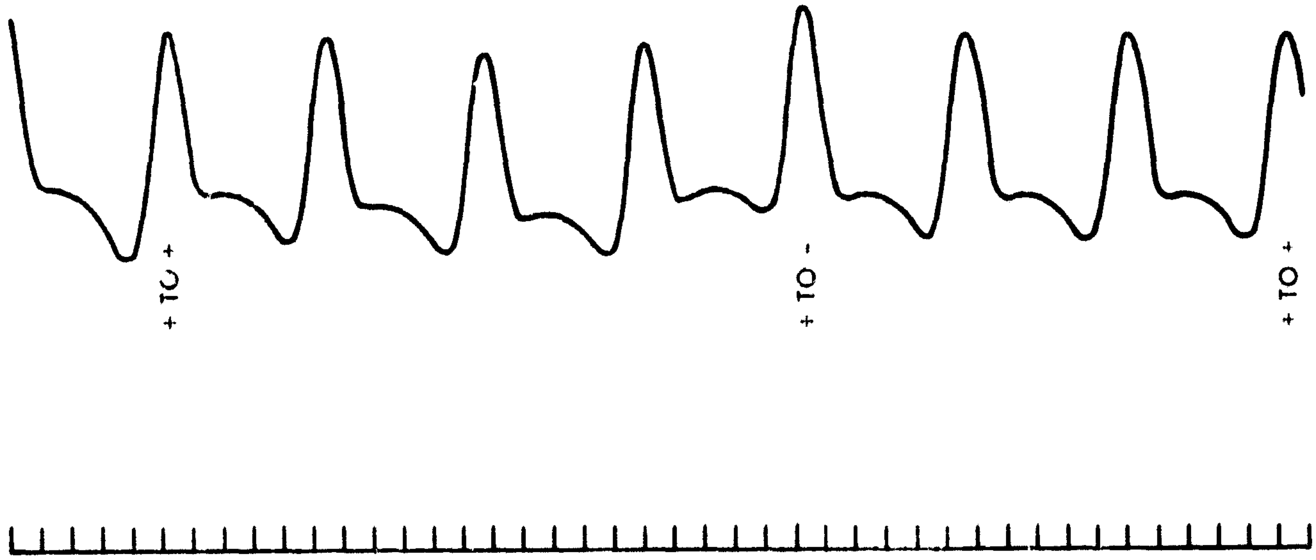
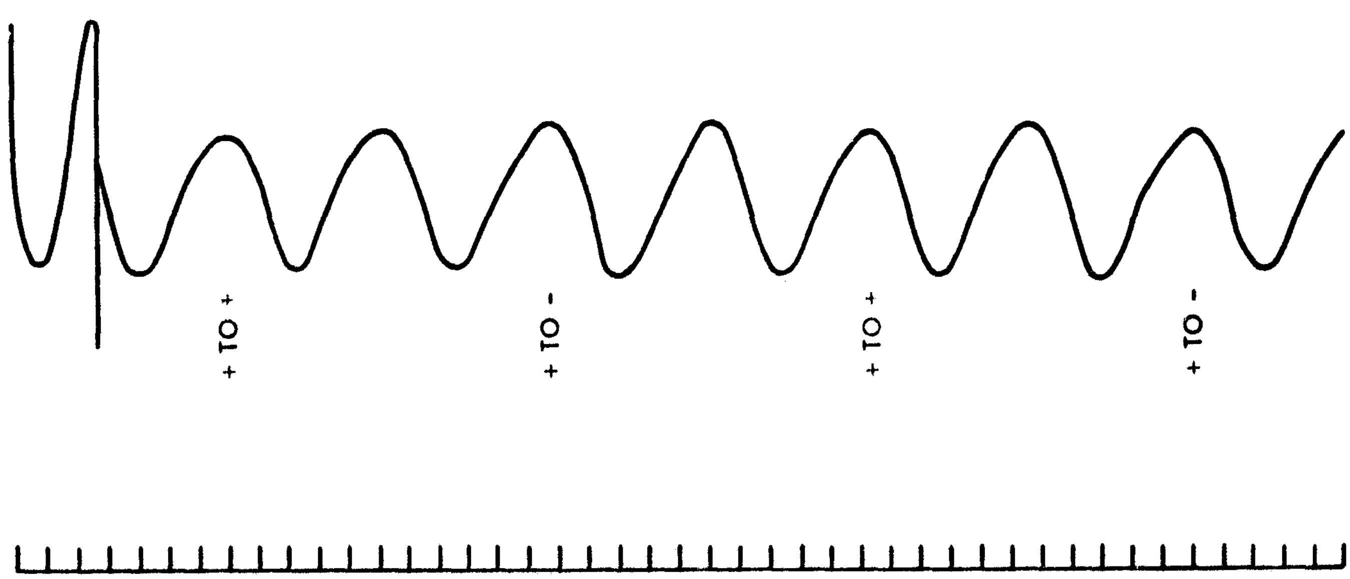



**Figure 5. Variation of Magnetometer Output with ATS Simulator Rotation**




41-INCH SEPARATION - BANDPASS MODE 0.2 TO 1.5Hz




41-INCH SEPARATION - BANDPASS MODE 0.2 TO 0.2Hz

**Figure 6. Variation of Magnetometer Output with ATS Simulator Rotation**

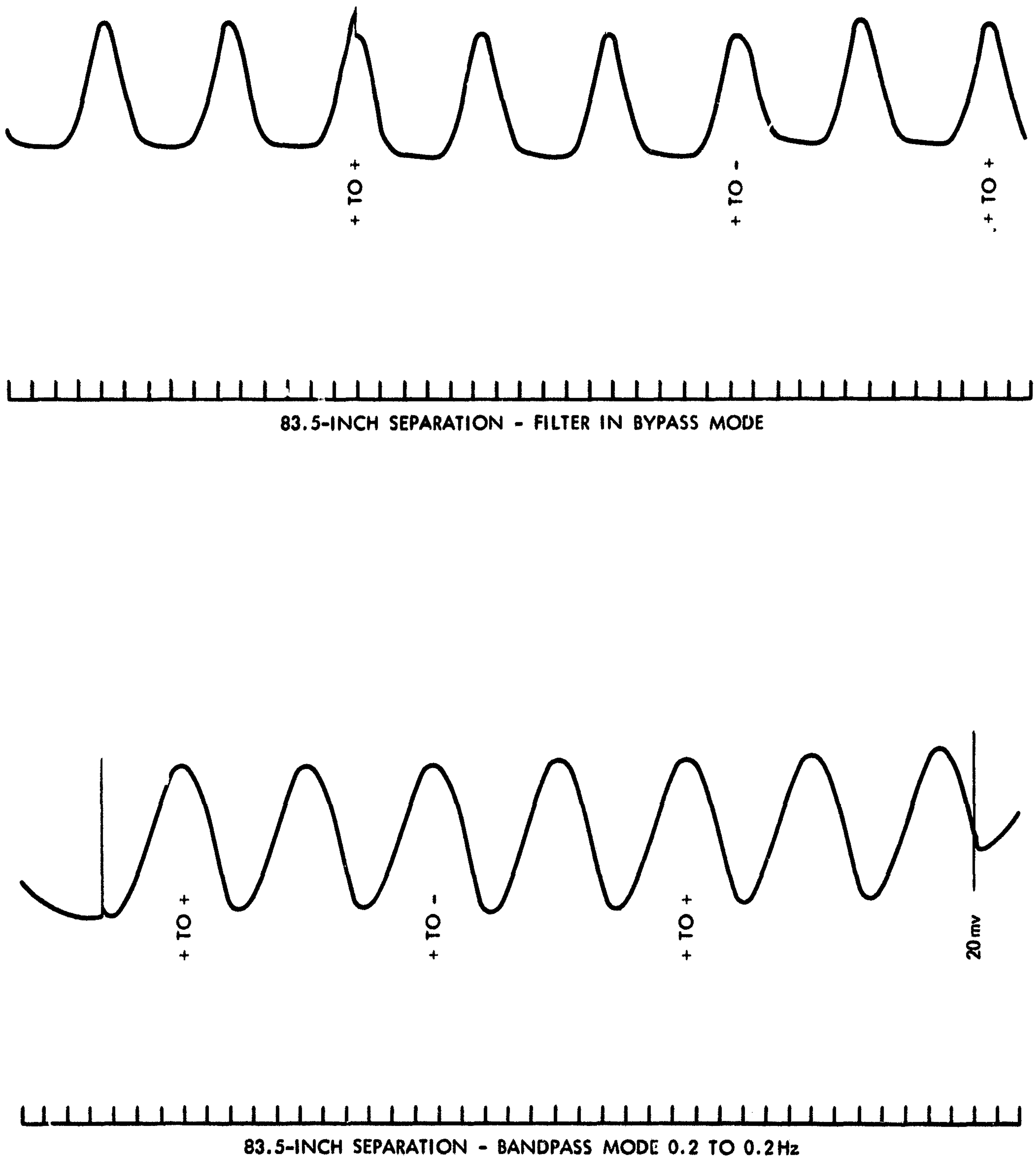



**Figure 7. Variation of Magnetometer Output with ATS Simulator Rotation**

## Interaction Torque Measurement

Figure 8 is a plot of the data listed in Table 2. The curve is symmetrical about the 180-degree position with torque reversal occurring at about 42 degrees and again at 318 degrees. If the moment of the despin magnet were reversed at these positions, the torque on the ATS would be unidirectional.

Figure 9 is a plot of the data listed in Table 3. Although the magnets were still in the "as-received" magnetic state, the despin magnet was oriented perpendicular to the line of centers as shown in Figure 9. The torque levels developed are significantly less than those for the "in-line" case. In addition, another torque reversal occurs per cycle.

Figure 10 is a plot of the data listed in Table 4. These data were taken through only one-half a rotation, the curve being symmetrical, with both magnets in the fully charged state. The separation distance was slightly greater (2 feet 8.25 inches versus 2 feet 6 inches for the "as-received" tests).

In addition to the torque data taken at the foregoing separation distances, measurements were made at several other spacings to determine the angle at which torque reversal occurred. Table 4 lists the results. A plot of the torque reversal angle versus the separation distance is a straight line (Figure 11).

## Magnet Charging

Figure 12 shows the maximum flux density obtained as a result of repeated charging at a specific voltage level. Figure 13 indicates the percent of this maximum attained on the first reversal after fully charging in one direction. It was found that the magnets could be completely reversed in moment polarity with one pulse using a 350-microfarad capacitor charged to 112 volts. Cathode-ray oscilloscope observation of the voltage developed across a precision resistor indicated that the time required for complete reversal is approximately 0.02 second.

## Magnetic Measurements

The magnetic observations demonstrated that the magnetometer probe can be manually aligned so that it views only 5 to 10 gammas when only a few inches away from the end of the fully charged despin magnet. Subsequent installation and rotation of the simulated ATS magnet resulted in the magnetometer records shown in Figures 5 through 7. Note that reversal of the polarity of the despin magnet produced both a dc offset and a step discontinuity at the moment of reversal (Figures 5 and 7) and that higher harmonics, as well as the fundamental rotational frequency, appear in the magnetic-field record. These characteristics

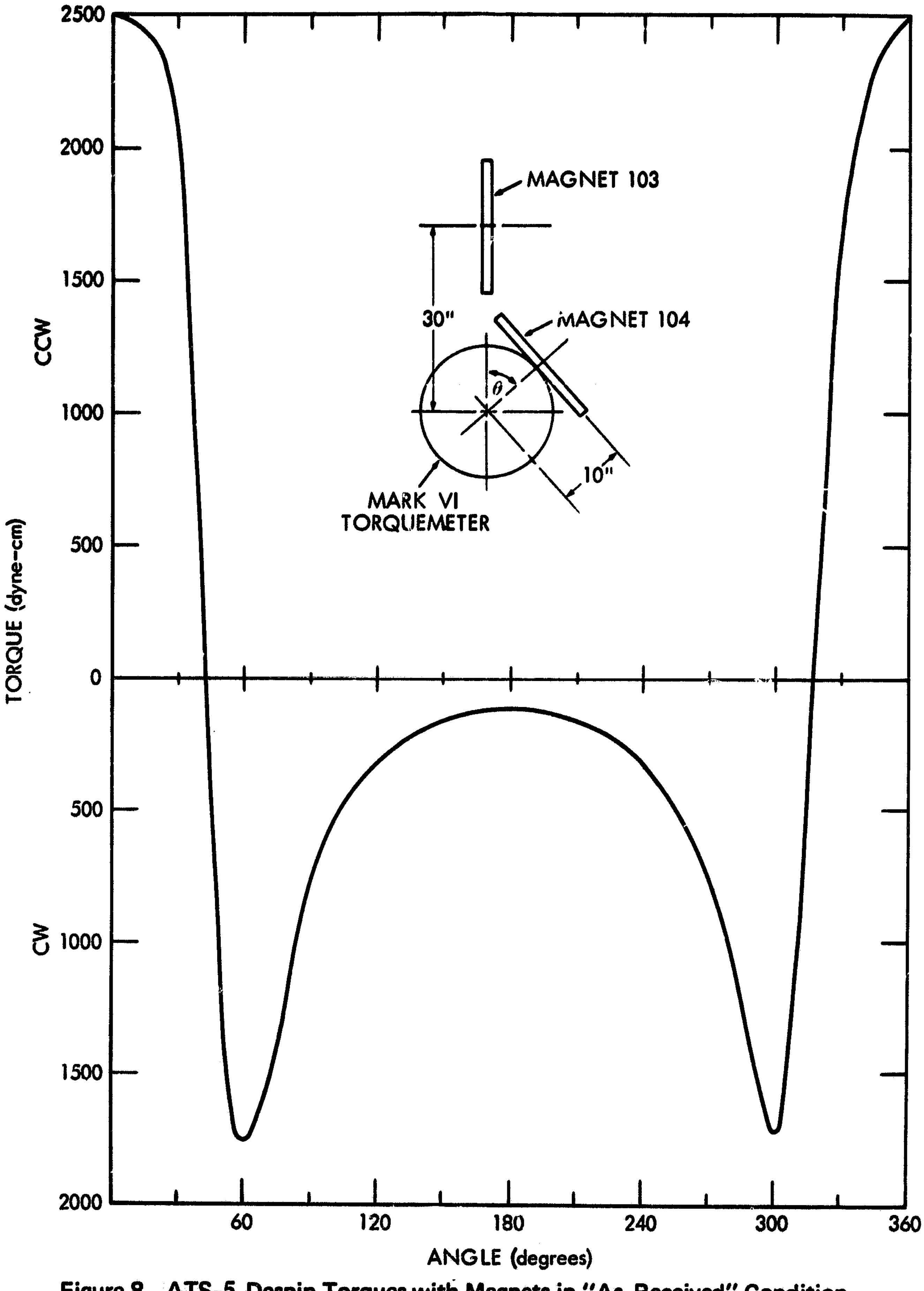



**Figure 8. ATS-5 Despin Torques with Magnets in "As-Received" Condition**

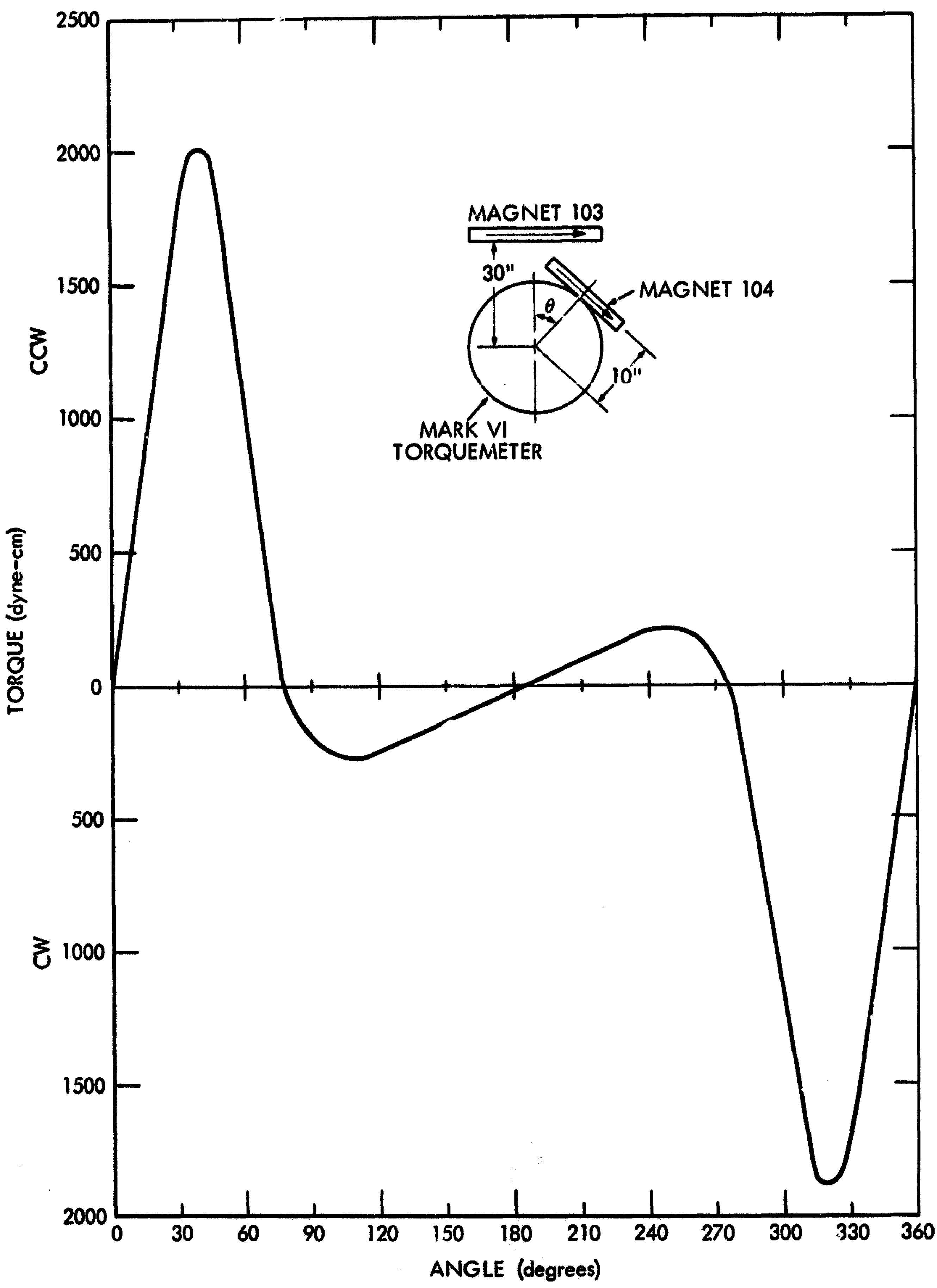



Figure 9. ATS-5 Despin Torques with Torquer Normal

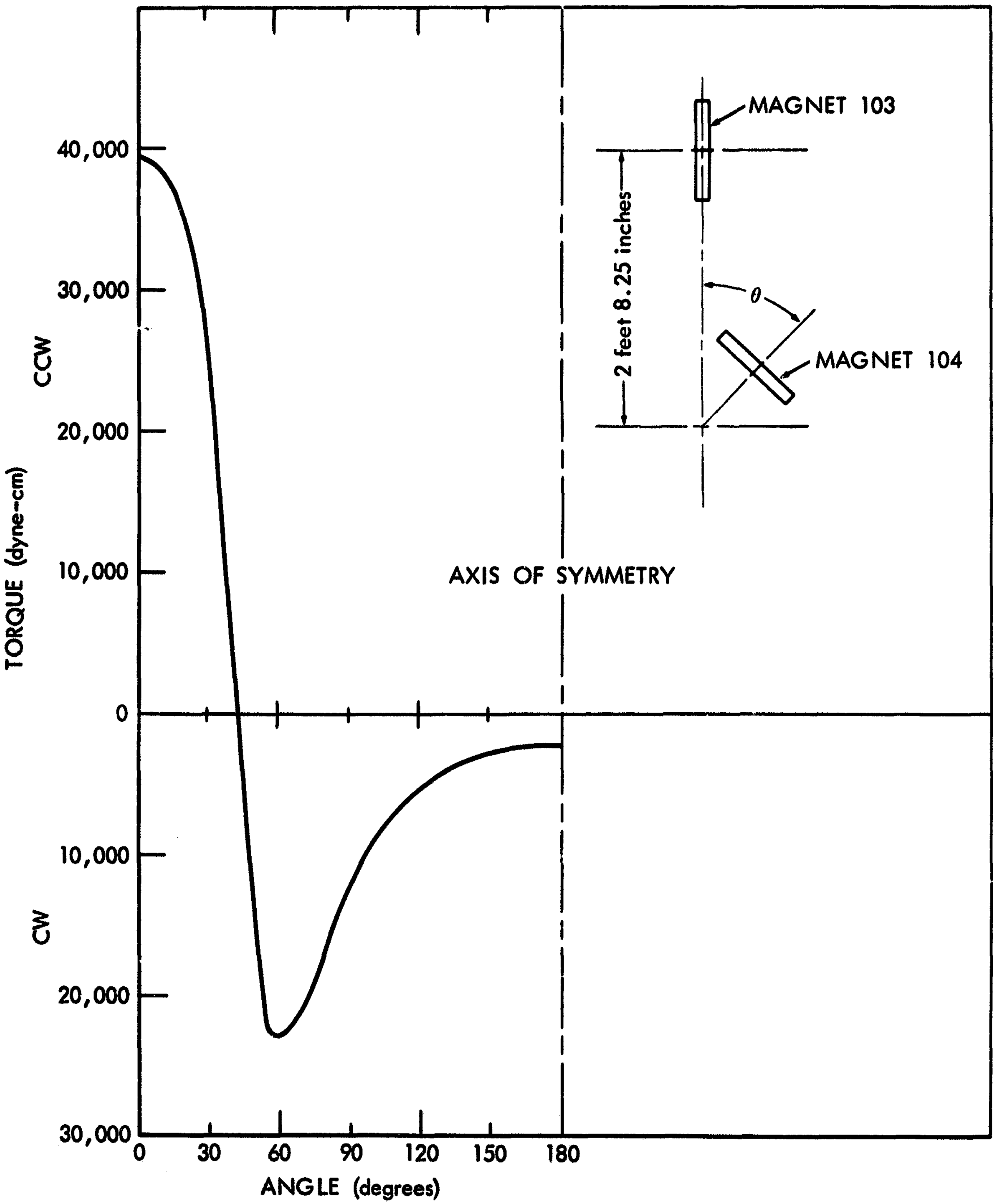



**Figure 10. ATS-5 Despin Torques with Both Magnets Fully Charged**

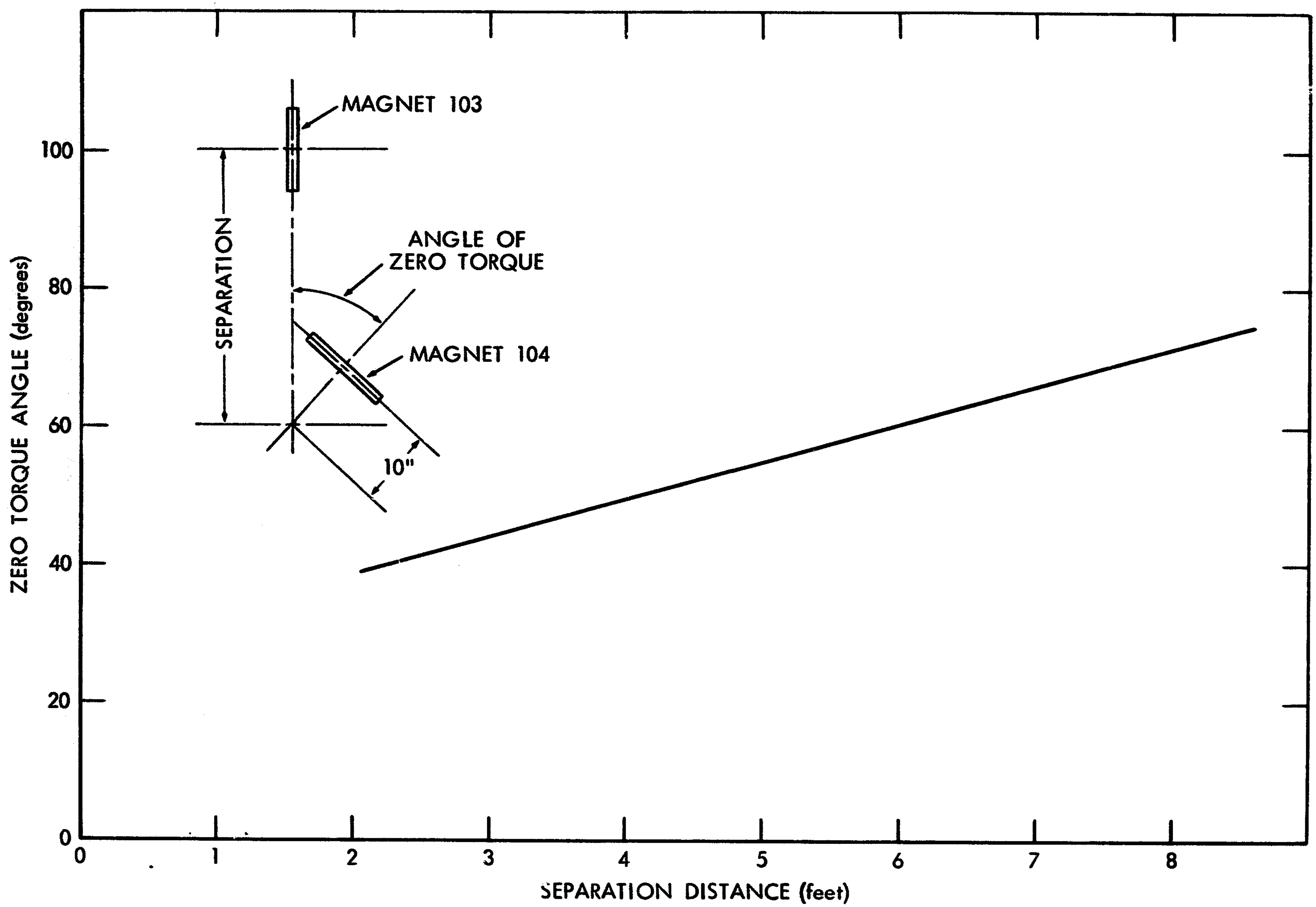



Figure 11. ATS-5 Despin Torques (Variation of Zero-Torque Angle with Separation)

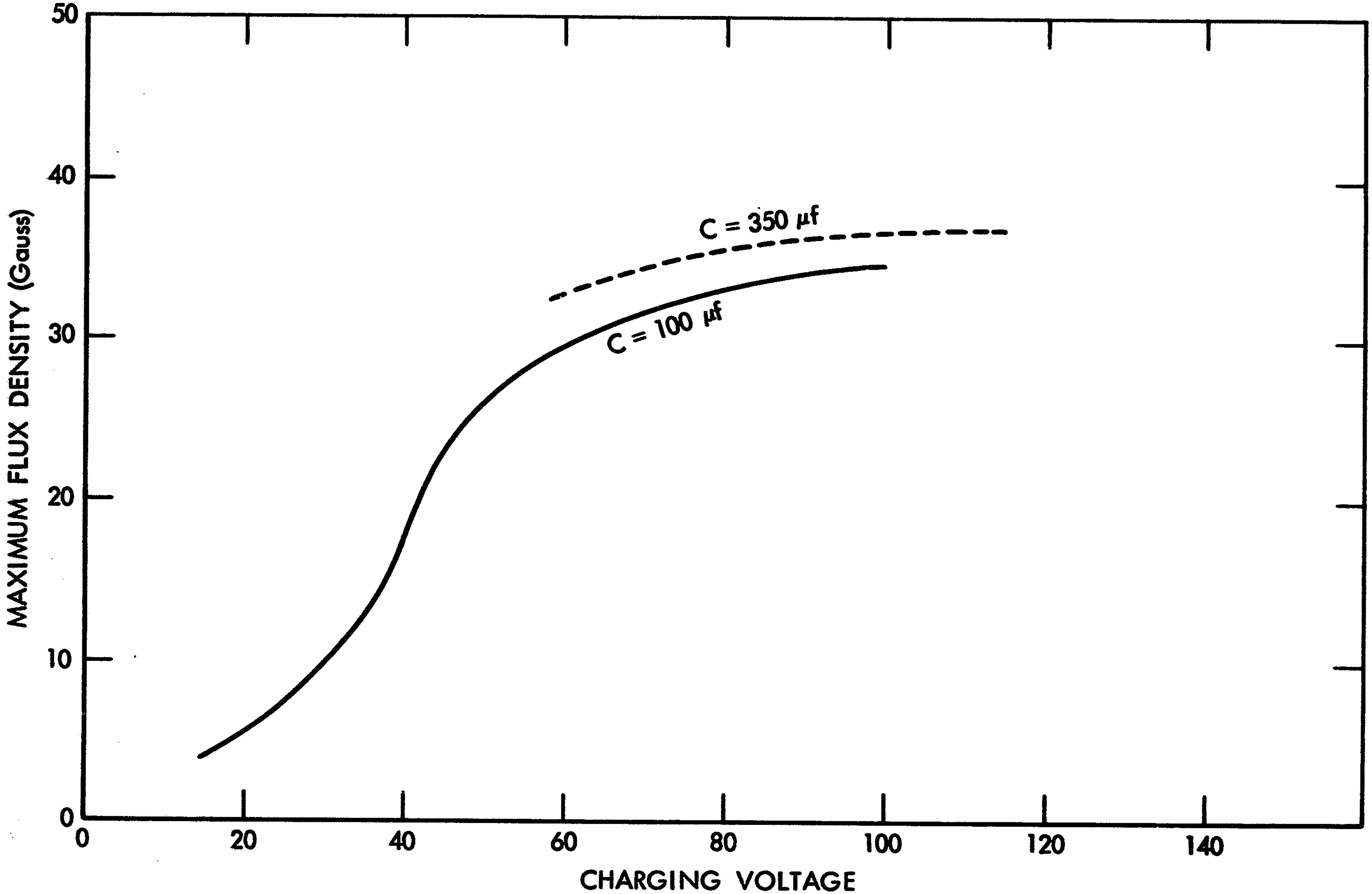



Figure 12. Electromagnet 103 Capacitive Pulse-Charging Characteristic

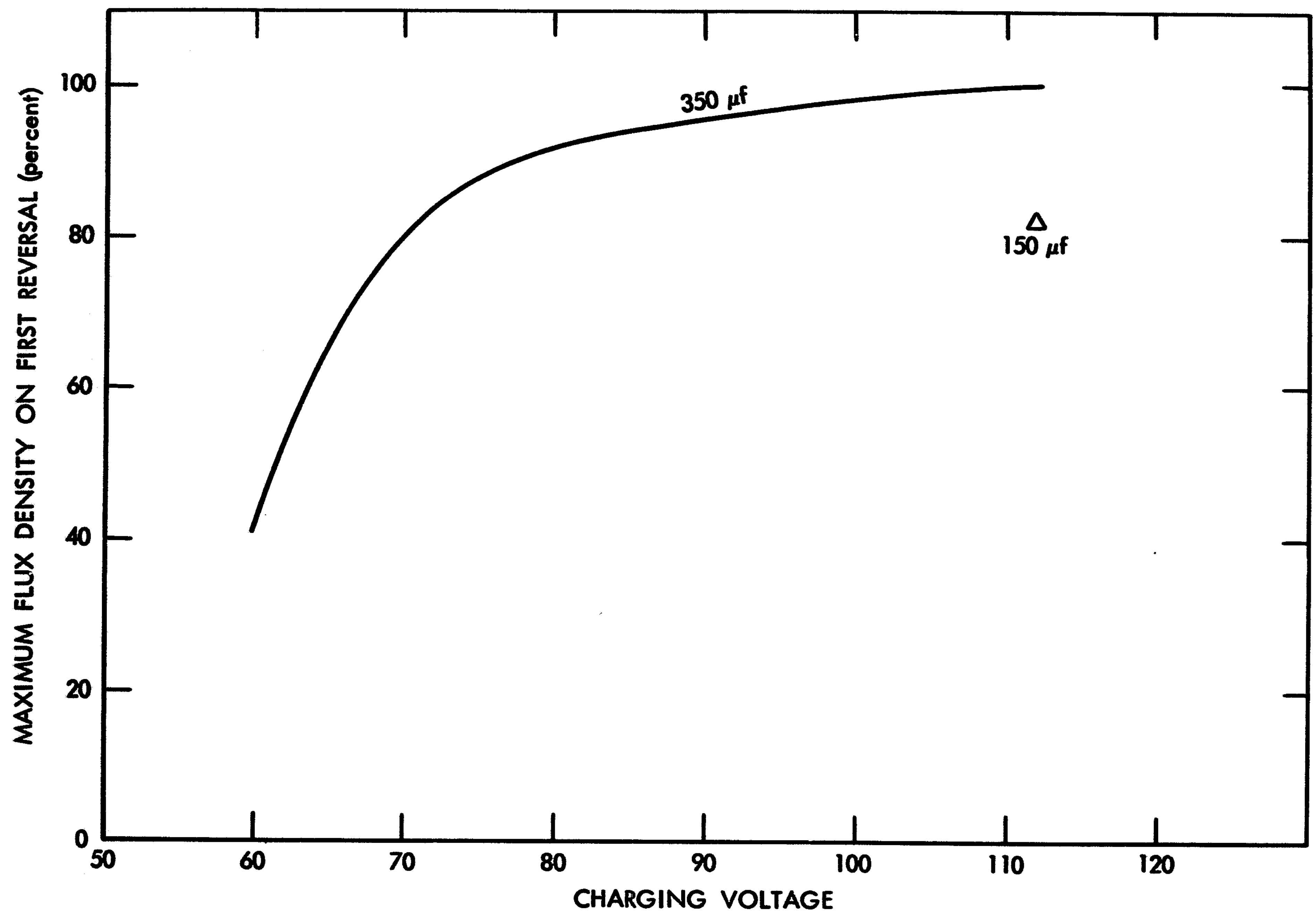



Figure 13. Electromagnet 103 Reverse-Charge Characteristic

are undesirable if the magnetometer record is to be used as an indicator of the angular orientation of the ATS satellite.

Data shown in Figures 5, 6, and 7 were obtained with varying degrees of signal filtering. The cleanest records were obtained when the filter was operated in the narrow-bandpass mode, with high attenuation of everything except the fundamental of 0.2 cycle per second. These records are essentially sinusoidal, with no discontinuity or dc offset as a result of reversing torquer-magnet polarity

## CONCLUSIONS

This testing program has provided valid experimental data for refining the mathematical model used to predict the performance of any specific satellite despin design.